1 INSTRUCTIONAL SUPPORT

1.1 Instructor

Instructor: Beth Parker, Ph.D.
Office: RICH 3503, ext. 53642
Email: bparker@uoguelph.ca
Office hours: TBA on Courselink or by appointment

2 LEARNING RESOURCES

2.1 Course Website

Course material, news, announcements, and grades will be regularly posted to the ENGG*6910 Courselink site. You are responsible for checking the site regularly.
2.2 Required Resources

Harrison et al. (1992) WRR 28:515-526
Cherry et al. (2014) The Bridge Article
Neuzil et al. (2013) Eos, Vol. 93, No. 30

2.3 Recommended Resources

Davis & DeWiest
Eriksson, Gustafsson & Nilsson (1966)
Hiscock (Freeze & Witherspoon summary, etc.)
Schwartz & Zhang
Hubbert (1940) flow system diagram
Toth (1963) Classic paper
Meyboom (1962) Prairie profiles classic overview paper
Cherry (1987) Chapter 14 Canadian Aquatic Resources
Cherry, Grisak & Clister (1973)
Van der kamp & Maathuis (1985) Conference paper
Johnson et al. (1989) ES&T
Parker et al. (2004) JCH North Haven Aquitard
Grisak et al. (1970s) bulk fracture porosity
McKay et al. (1993) ES&T; Ruland et al. (1991)
Schwartz & Zhang pp. 146-152
Freeze & Cherry pp.70-75
Parker et al.(1994) Ground Water
OHara et al.(2000) WRR
Schwartz et al. (1982) WRR 18:535-545 Regina case study (PCBs)
Mcleluain et al. (1989); Wills et al. (1992) Smithville
Mette Broholm papers
Wolff (1970) WRR 6:194-203
Freeze & Cherry (1979) Chapter 8 pp.314-324
Kent Keller et al. (1989) WRR 25:2299-2317
Subsidence case studies (Central Valley, CA; Mexico City, Italy, etc.)
Freeze & Cherry (1979) pp. 370-375
AWWARF (2006) Chapter 3 Head Profiles
CFB Borden Case (head, isotope and DNAPL tracers)
Meyer et al. (2008) J. Env. Geology
Hart et al. (2007) Ground Water
Einaron & Cherry CMT paper or Nielson book MLS Chapter (2005)
Parker, Cherry & Swanson (2007) GWMR
Vince Cloutier, Frape et al. paper
AWWARF Report sections; Mudstone Book Chapt 5 (origins)
Chris Neuzil (1988) Ground Water 26:784- (Pierre shale)
Neuzil (1994) WRR 30:145-150
Witherspoon papers
Petroleum Engineering literature
Carbon disposal (Tim Parker presentation)
publications and reports for each of the proposed repository sites (Andra site in France, Swiss, Belgium, Ontario, etc.)
Site Assessment methods (lab and field, prediction over long term)
Diffusion parameters,
AL et al. (2008) diffusion measurements in rock, sorption of radionuclides-diffusion, sorption, (Gillham 1980s Sr, Cs)

2.4 Additional Resources

Lecture Information: All the lecture notes are posted on the web page (week #1-#6).

Assignments:

1) Four class assignments will be due 1 week after assignment is made.
2) Download the assigned readings on a weekly basis and prepare to participate in topic discussions.
3) Class report project and powerpoint presentation on approved topic relevant to class.

3 Assessment

3.1 Dates and Distribution

Class Assignments: 40%
Class Participation: 20%
Class Project and Presentation: 20%
Final Exam (Oral): 20%

3.2 Course Grading Policies

Missed Assessments: If you are unable to meet an in-course requirement due to medical, psychological, or compassionate reasons, please email the course instructor. See the undergraduate calendar for information on regulations and procedures for Academic Consideration: http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml

Accommodation of Religious Obligations: If you are unable to meet an in-course requirement due to religious obligations, please email the course instructor within two weeks of the start of the semester to make alternate arrangements. See the graduate calendar for information on regulations and procedures for Academic Accommodation of Religious Obligations: http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-accomrelig.shtml

4 AIMS, OBJECTIVES & GRADUATE ATTRIBUTES

4.1 Calendar Description

This course concerns groundwater flow systems and the role of aquitards in these systems with and without pumping for water supply. The hydrology and hydrochemistry of most aquifers are governed by aquitard influences and yet the literature concerning the role of aquitards in groundwater systems is relatively sparse and not well-integrated. Representative geologic domains will be examined using multiple types of evidence to discern flow system characteristics and present various conceptual models from field-based research studies. Topics of interest include: flow pattern characteristics, groundwater age and residence time, discerning advection versus diffusion dominated domains, aquitard integrity for aquifer protection and implications of flow system delineation and aquitard characteristics concerning selection, design concepts and monitoring of waste disposal sites (e.g. siting and designing solid (municipal) and hazardous (industrial) waste landfills, deep radioactive waste repositories, carbon sequestration, petroleum storage, etc. ) in the context of shallow, intermediate and deep flow systems. The course is comprised of lectures, class discussions, and student projects and presentations based on literature reviews and / or applications of mathematical models to evaluate concepts and explore relevant aquitard topics to the profession.

4.2 Course Aims

The objective of this course is to provide a sound understanding of the role of aquitards in groundwater flow systems and their role in land disposal/entombment of wastes and natural resource extraction. The main goals of this course are to:
1) Examine representative geologic domains using multiple types of field, lab and modeling data to provide evidence of flow system characteristics and quantified process-based site conceptual models
2) Analyze various hydrogeologic system conditions from field-based research studies including shallow freshwater zone and deep brackish zones
3) Discuss hydrology and hydrochemistry and relation to governing aquitard influences

4.3 Learning Objectives
At the successful completion of this course, the student will have demonstrated the ability to:
   1. Understand groundwater flow systems and the role of aquitards in these systems.
   2. Understand aquitard integrity and characteristics concerning design concepts and monitoring of waste disposal sites, hazardous waste landfills and deep radioactive waste repositories.
   3. Critically review technical literature related to Groundwater resource protection and waste management
   4. Understand environmental threats from deep sedimentary rock aquitards targeted for unconventional oil and gas extraction, coal and mining

4.4 Instructor’s Role and Responsibility to Students
The instructor’s role is to develop and deliver course material in ways that facilitate learning for a variety of students. Selected lecture notes will be made available to students on Courselink/D2L but these are not intended to be stand-alone course notes. During lectures, the instructor will expand and explain the content of notes and provide example problems that supplement posted notes. Scheduled classes will be the principal venue to provide information and feedback for presentations and project.

4.5 Students’ Learning Responsibilities
Students are expected to take advantage of the learning opportunities provided during lectures and discussions. Students, especially those having difficulty with the course content, should also make use of other resources recommended by the instructor. Students who do (or may) fall behind due to illness, work, or extra-curricular activities are advised to keep the instructor informed. This will allow the instructor to recommend extra resources in a timely manner and/or provide consideration if appropriate.
5 Teaching and Learning Activities

5.1 Timetable

3 hour lectures, 2 days a week – schedule TBA.

5.2 Course Topics and Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture Topic</th>
</tr>
</thead>
</table>
| 1    | Aquitards in Regional Groundwater Flow System context  
Geologic Origins of Non-indurated Aquitards- Aquifer Systems and Relevance to Hydrogeologic Properties |
| 2    | Characterization of Clayey Aquitards: Approaches and Methods  
Diffusion- controlled Aquitards: natural solutes. (eg major ions , isotopes)  
Groundwater Velocity, Age and Residence Time: contrasts between porous and fractured media  
Geologic Origin and Characteristics of Bedrock Aquitards |
| 3    | Characterization Methods for Bedrock Aquitards  
Role & Use of Aquitards in (deep) Waste Disposal and unconventional gas extraction |
| 4    | Hydraulic characterization methods  
-Single & multi well tests  
-Steady state and transients  
-Hydraulic head profiles |
| 5    | Role of Aquitards In Contaminant Transport and Fate:  
-Aquitard Integrity & Groundwater Resource Protection (assessing current conditions versus predicting future impacts)  
-Vulnerability Assessment |
| 6    | Aquitards in Contaminated Site Remediation  
- Effects of Mass Storage and Release from Low Permeability (Aquitard) Zones |
ACADEMIC MISCONDUCT

The University of Guelph is committed to upholding the highest standards of academic integrity and it is the responsibility of all members of the University community faculty, staff, and students to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the University’s policy on academic misconduct regardless of their location of study; faculty, staff and students have the responsibility of supporting an environment that discourages misconduct. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member.

5.3 Resources

The Academic Misconduct Policy is detailed in the Undergraduate Calendar: [http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml](http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml)

A tutorial on Academic Misconduct produced by the Learning Commons can be found at: [http://www.academicintegrity.uoguelph.ca/](http://www.academicintegrity.uoguelph.ca/)

Please also review the section on Academic Misconduct in your Engineering Program Guide.

The School of Engineering has adopted a Code of Ethics that can be found at: [http://www.uoguelph.ca/engineering/undergrad-counselling-ethics](http://www.uoguelph.ca/engineering/undergrad-counselling-ethics)